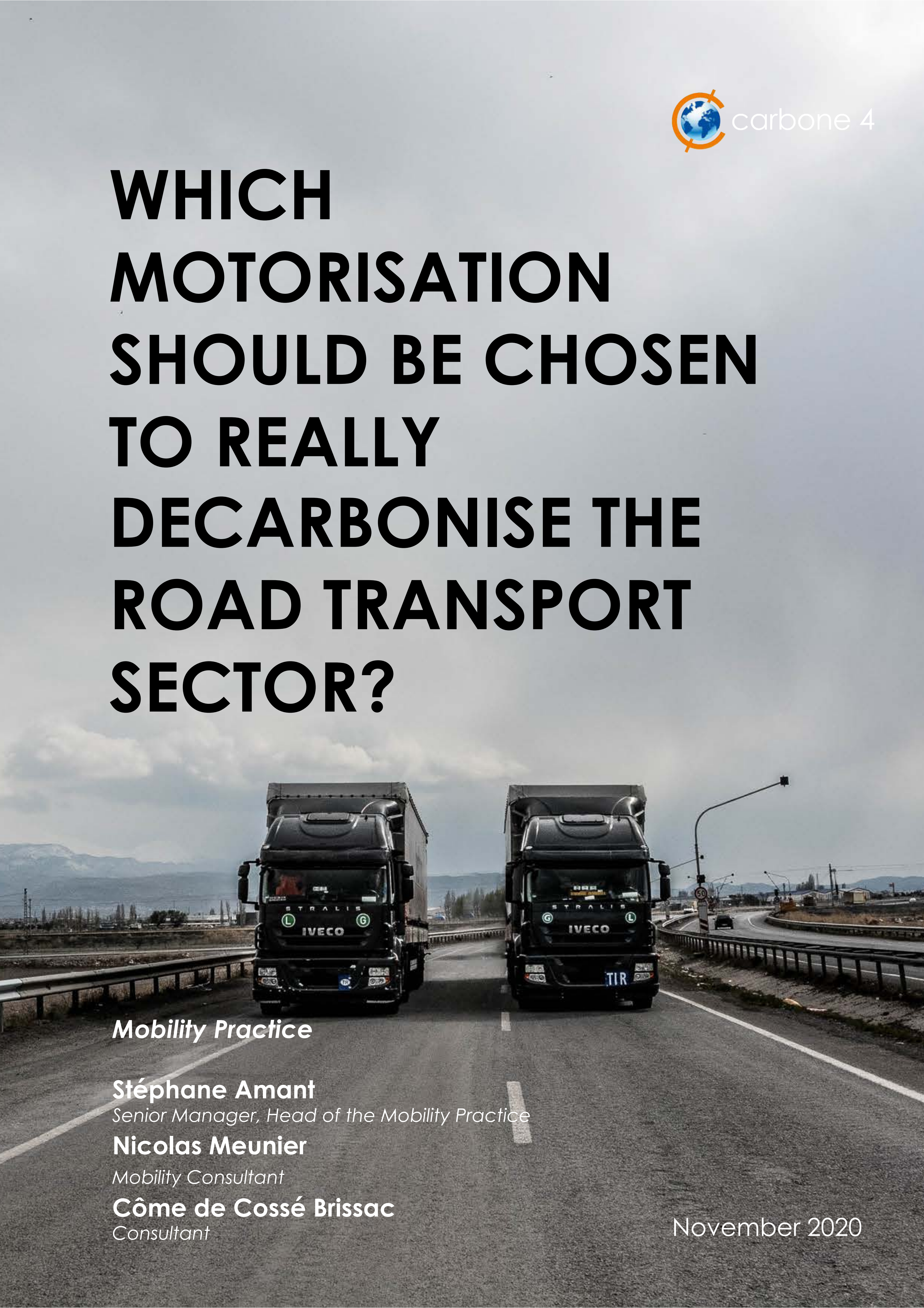


carbone 4

WHICH MOTORISATION SHOULD BE CHOSEN TO REALLY DECARBONISE THE ROAD TRANSPORT SECTOR?

Mobility Practice

Stéphane Amant
Senior Manager, Head of the Mobility Practice
Nicolas Meunier
Mobility Consultant
Côme de Cossé Brissac
Consultant

November 2020

Context and purpose of the study

In order to respond to the climate challenge, the mobility sector has no choice but to reinvent itself, particularly the road transport sector, for both people or goods. Through new technologies, new uses and by acting on demand: the challenge is so great that all the levers will have to be activated.

Regarding the technological lever, despite the announcements of the major industrial players and the intentions declared by the stakeholders, the path of the energy transition has not yet been clearly mapped out: it is difficult to affirm today with certainty which will be the most relevant alternatives to fossil fuels, between bioNGV, liquid biofuels, battery-electric, hydrogen or hybrid electric. In order to rank these different available energy options, one of the main metrics to compare will be **the carbon footprint over its life cycle**, taking into account the manufacture, usage and end of life of the vehicles, as well as **the "well to wheel"[1] approach for the energy carriers.**

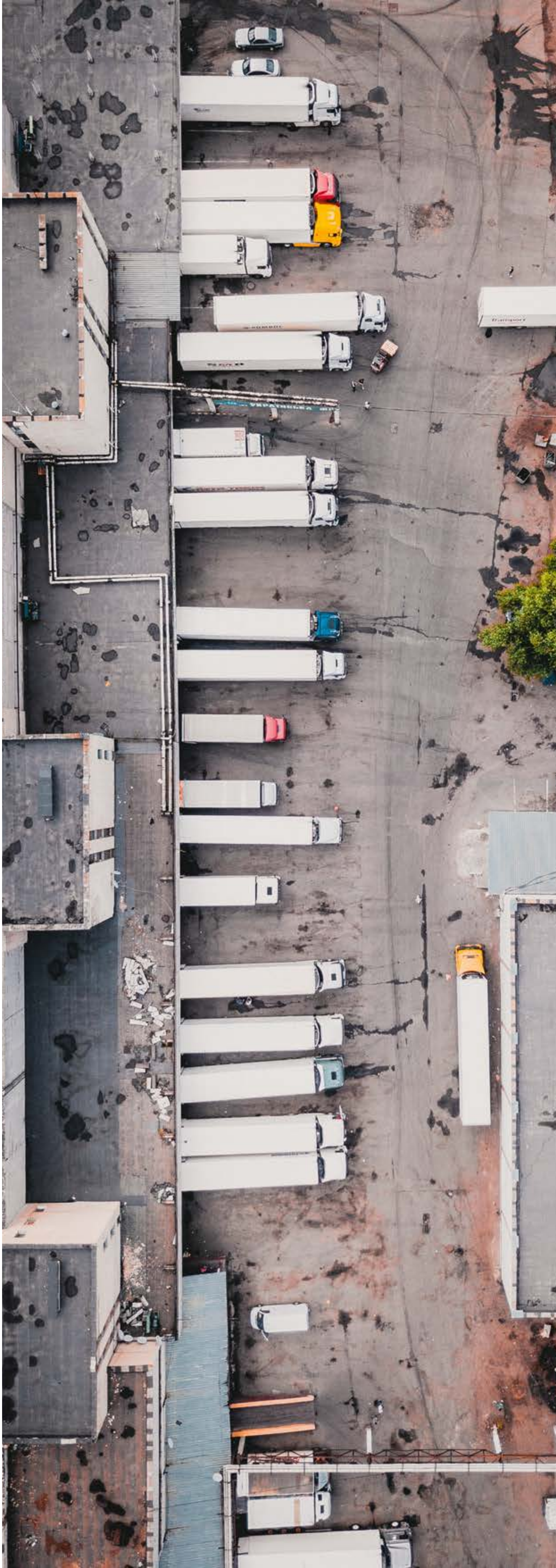
This summary for decision-makers presents the most recent results obtained by Carbone 4 on this subject, for Light Commercial Vehicles (LCVs), buses and semi-trailer trucks. The aim is to enlighten the debate and help stakeholders to make the best decisions with full knowledge of the facts.

The assumptions used, detailed results and sensitivity analyses are available in our detailed publication. It should be noted that for internal combustion engines, the incorporation of biofuels within diesel or gasoline and of biomethane in CNG (Compressed Natural Gas) is taken into account[2].

Glossary

GHG	Greenhouse Gas
ICEV	Internal Combustion Engine Vehicle
BEV	Battery Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
HDV	Heavy-Duty Vehicle
NGV	Natural Gas for Vehicle
CNG	Compressed Natural Gas

1. From production/extraction to final use in the vehicle.
2. E.g.: for ICE Diesel, the calculations take into account an increasing percentage of biodiesel over time.



BIO-NGV, BATTERY-ELECTRIC AND DECARBONISED HYDROGEN ON THE PODIUM

When considering the carbon footprint of a commercial vehicle (LCV, bus or semi-trailer truck) over its life cycle, e.g. its manufacture, then its use over 12 years and finally its end of life (see **Figure 1**, **Figure 2** and **Figure 3**), **the least emitting vehicles are:**

Vehicles using bioNGV

ICEVs running on bioNGV have a carbon footprint reduction of around 75% compared to a diesel combustion vehicle. This favourable conclusion applies regardless of the type of vehicle considered (LCV, bus or semi-trailer truck). The very low carbon footprint is due to the emission factor of biomethane (44 gCO2e/kWh[3]) and the assumption that gas vehicles would be developed with mild hybridisation (as with conventional combustion vehicles). The emission factor of biomethane varies little according to the country of production, and this observation remains valid throughout Europe. On the other hand, the potential of available biomethane for heavy mobility is limited (see below).

It should be noted that the methanisation production chain has co-benefits that result in avoided emissions at the level of the waste treatment system or the agricultural system. These co-benefits cannot be transferred to the emission factor of the biomethane produced but are fully recoverable as a contribution to the decarbonisation of the other sectors (see insert in the detailed publication).

Battery-powered electric vehicles, regardless of the electric mix in the region in question

BEVs have a 60 to 85% reduction in their carbon footprint compared to a fossil fuel vehicle, regardless of the country under consideration, despite the manufacture of the battery and its recycling.

A decarbonised energy mix (France, renewable electricity) provides the best performance, but even a BEVsold today in Germany or even Poland remains much less emissive than a comparable ICEV.

3. ENEA-Quantis study for GRDF - Evaluation of the GHG impacts of biomethane injection - March 2020.

Electric vehicles powered by hydrogen (FCEV) produced by electrolysis or biomethane steam reforming, with decarbonised electricity (French grid or renewables)

FCEV has very good results provided that the hydrogen itself is low carbon! If the hydrogen is produced by electrolysis, the electricity must be decarbonised (as in France or with renewable energies). Conversely, production by electrolysis with grid electricity leads to very unfavourable results in countries such as Germany or the Benelux countries. Similarly, if hydrogen is produced by steam reforming, it must be produced with biomethane, which then raises the question of the proper allocation of a limited resource.

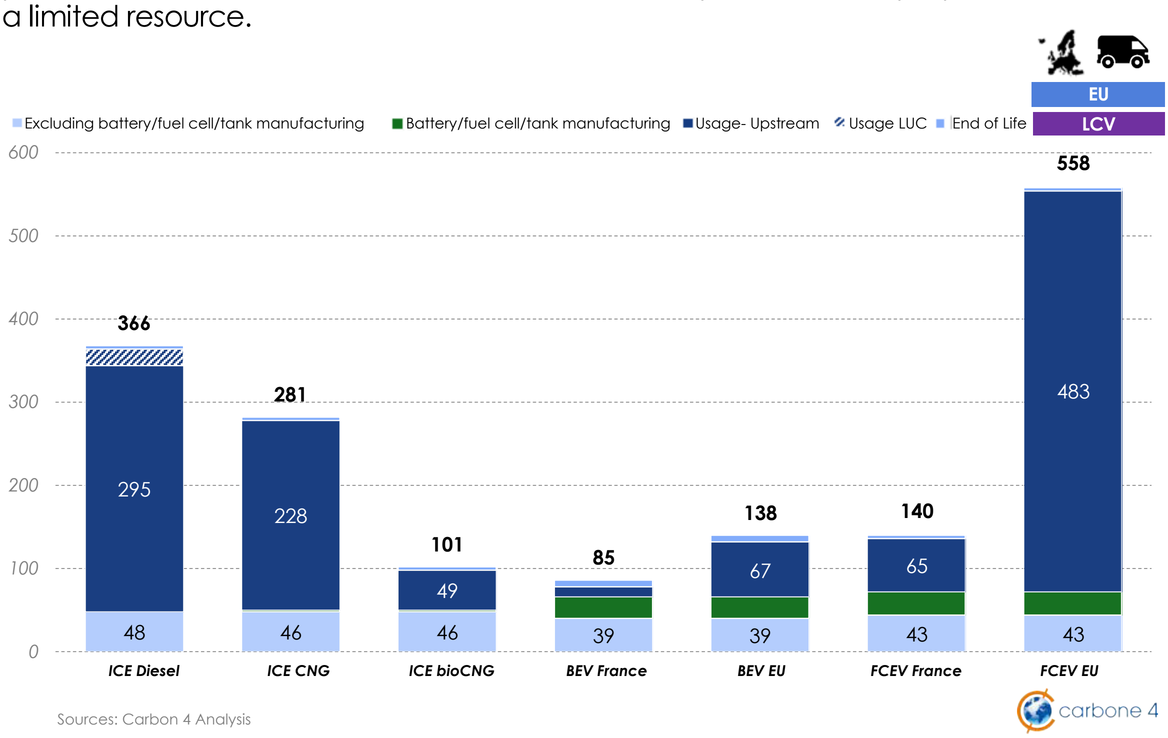


Figure 1 - Average carbon footprint over the lifetime of a LCV sold in 2020 Europe – LCV large van type | gCO2e/km

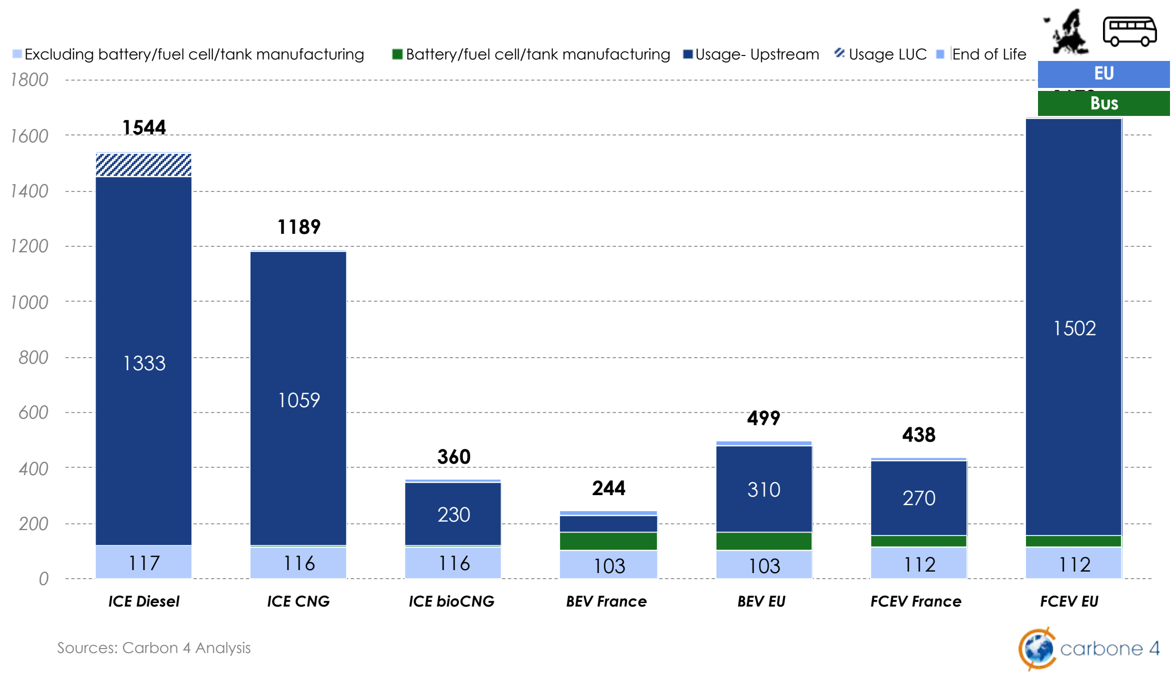


Figure 2 - Average carbon footprint over the lifetime of a bus sold in 2020 Europe - Bus 12m | gCO2e/km

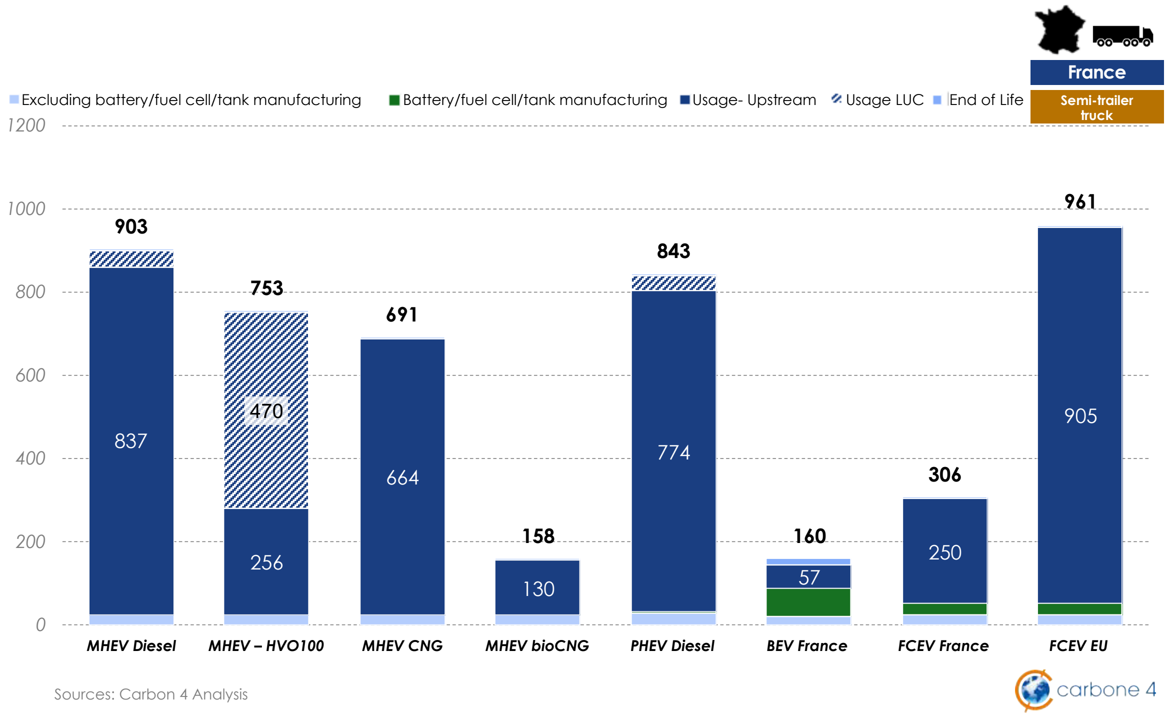


Figure 3 - Average carbon footprint over the lifetime of a road tractor sold in 2030[4]
France – Semi-trailer truck 40 t | gCO2e/km

The potential for low-carbon hydrogen production will remain low for many years to come, in order to cover a multiplicity of needs (especially industrial needs). In the short term, this should be an incentive for reserving this technological option for cases where BEVs reach their limits (e.g. long-distance goods transportation by heavy-duty vehicles (HDVs), buses travelling daily distances in excess of 200 km without the possibility of recharging, LCVs widely used by craftsmen without a charging point at home, etc.). In the long-term, the supply of low-carbon hydrogen will make it possible to supplement the limited supply of bioNGV (see below) and to continue to overcome the shortcomings of BEVs.

Interesting nuances are to be specified, depending on the type of vehicle.
Regarding the **LCVs and buses circulating in urban areas**, the electric and hydrogen (low carbon) engines are preferred due to the absence of NOx and fine particle emissions (from the exhaust), compared to the bioNGV. It should be noted that thanks to the **high energy recovery** during frequent braking, the BEV in this case has the best carbon performance.
Conversely, **biomethane is the only truly decarbonising technological solution available to date for semi-trailer trucks**, pending the arrival of "zero-emission" solutions.

Finally, ICEV running on **NGV (excluding bioNGV), hybrid combustion vehicles and even liquid biofuels[5] will bring few gains by 2040**: these solutions are not up to the task in terms of the decarbonisation expected for the road transport sector.

4. ENEA-Quantis study for GRDF - Evaluation of the GHG impacts of biomethane injection - March 2020.
5. Direct and indirect land-use change taken into account in the study, contrary to European regulations to date.

A FOCUS ON BIOFUELS AND BIOMETHANE

Liquid biofuels only provide a modest decarbonisation, because on the one hand their incorporation rate in diesel and petrol is relatively low (~5% of the energy share of fuel in Europe in 2020, estimated at around ~10% for 2035), and on the other hand the carbon footprint of some agrofuels is similar to, or higher, than that of fossil fuels, taking into account the changes in land use[6] (see publication).

Thus, **regarding biodiesel in 2030**, even with some favourable assumptions (such as the elimination of palm oil, which accounted for 25% of biodiesel consumption in Europe in 2019), **there is little improvement in the carbon footprint**. When using pure biofuels (HVO100[7]), the footprint is reduced by only 20% (see **Figure 4**).

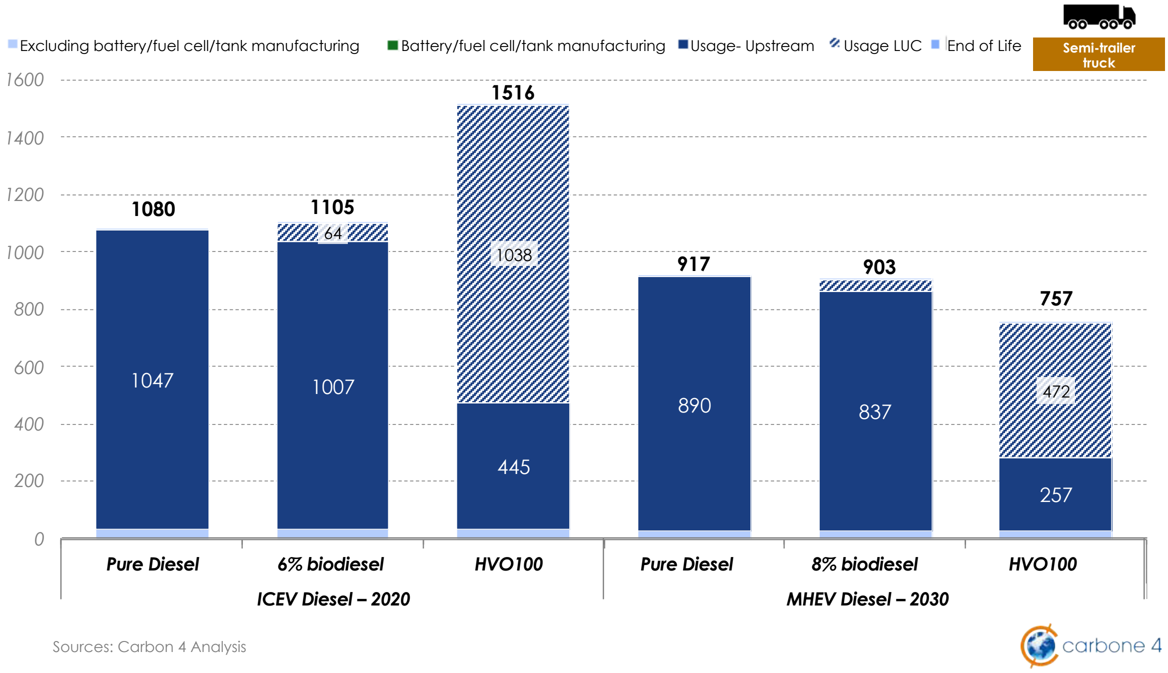


Figure 4 - Comparison of the average carbon footprint over the lifetime of a semi-trailer truck sold in 2020 and 2030 | gCO2e/km

Concerning biomethane, our calculations confirm that it represents **an excellent way to decarbonie road transport.** However, **the use of bioNGV has less impact than electrified solutions on the reduction of air pollution or noise in dense areas**.

An apparently strong advantage of the gas sector is that the **transportation and distribution networks are already in place**, which makes the question of refuelling infrastructures less of an issue.

6. Direct and indirect land-use changes taken into account in the study, contrary to European regulations to date.
7. Same composition of inputs as in the case of an incorporation rate of 6%/8% respectively.

However, this apparent advantage can also be seen as a risk for the climate: until bioNGV replaces fossil natural gas in significant proportions, users of gas vehicles will primarily burn fossil NGV, which will by no means reduce GHG emissions to the desired extent. **The accelerated development of gas mobility could even lead to locked-in transport GHG emissions for one to two decades, principally via fossil natural gas,** that is if the production of biomethane is insufficient.

> **"At best, 1/4 of all trucks could be running on bioNGV in 2050."**

The big question mark concerning biomethane is whether it is available at a large scale for the transport sector. According to an overview based on various reference studies (ADEME, IEA, ICCT, CERRE and Gas for climate: see publication), the range of possibilities for its production appears relatively vast. However, in order to establish the ideas, we have translated them into accounting terms; by showing what the objective of the National Low Carbon Strategy (in France) on renewable gas in transport meant in terms of supplying the fleet of vehicles with bioNGV by 2050 under favourable assumptions.

France - vision 2050		Comments
SNBC Demand	**40 TWh**	• Obj: 200-300 TWh of renewable gas (biomethane and hydrogen) in 2050, of which 40 TWh will be allocated to transport • Optimistic assumption: all the renewable gas in transport is biomethane
Average consumption of a bus / HDV	**306,700 kWh/year**	• Consumption and mileage recovery of the model for vehicles produced in 2030
Number of vehicles running on bioNGV	**130 000**	• French CNG vehicle fleet consisting solely of buses and HDVs
Share of the road vehicle fleet	**12%**	• Assumption for a stable road vehicle fleet of 1 M buses/HDVs

Sources : SNBC, MTES, gaz-mobilité.fr

Table 1 - Estimation of the potential share of the French road fleet of buses and HDVs running on biomethane in 2050

In this favorable scenario, **the proportion of HDVs that will run on 100% bioNGV in 2050 is around 12% (including buses).** Doubling the amount of biomethane available for transport[8] (from 40 to 80 TWh) would result in **a higher value of 24% of HDVs being able to drive with 100% bioNGV in France in 2050.**

This approach was reproduced in the EU and led to very similar results: **approximately 1/4 of European HDVs at best will be able to drive with 100% bioNGV in 2050, with 1/10 being probably more realistic.**

8. Either because the total production is higher than expected (closer to 300 TWh than to 200 TWh), or because the share reserved for transport has increased (e.g. 40% of the 200 TWh, instead of the 20% planned today).

TECHNOLOGY IS NOT THE ONLY LEVER

From the point of view of GHG emissions, the combination of bioNGV and battery electrification, complemented in a few years by hydrogen solutions, therefore seems the most relevant way to move towards low carbon LCVs and HDVs.

However, **it is crucial to remember that technology alone will not make it possible to reduce our emissions sufficiently** in the coming decades. The alternative solutions studied here have **many other impacts that must also be controlled**. Therefore, it is essential to mention here the other particularly effective reduction levers that already exist and that should be developed alongside:

- Reducing the flows at the source (the number and scope of movements) for goods
- Filling heavy vehicles better (eliminating empty returns and reducing non-optimised express deliveries)
- Encouraging a modal shift as much as possible towards more carbon-efficient mass transport (boat or train), or even active modes of transport in cities (cargo bikes), depending on the situation

TO BE FOUND IN OUR PUBLICATION

All results are not included in this synthesis and that is why we invite you to explore our complete publication on the subject. In particular, you will discover much more about the **factors in favour or against** each of the alternatives, a **detailed focus** on certain energy carriers (liquid biofuels, biomethane, hydrogen) and **sensitivity analyses**. And of course, all the **sources and assumptions** used.

It should be noted that this work also includes the case of **personal vehicles** (segments B and D), which were also examined in our analyses.

carbone 4

Carbone 4 is the first independent consulting firm specialised in low carbon strategy and adaptation to climate change.

We are constantly on the lookout for weak signals, we deploy a systemic vision of the energy-climate constraint and put all our rigour and creativity to work in transforming our clients into climate challenge leaders.

Within Carbone 4, the Mobility Practice is fully committed to work together with actors concerned by the transformation of the transport sector.

Contact: mobilite@carbone4.com